

## The Influence of AI Innovation on Economic Performance: A Panel Data Analysis on BRICS Countries

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### ABSTRACT

The incorporation of artificial intelligence (AI) in different industries has generated significant curiosity about its potential influence on economic expansion. This study investigates the correlation between AI advancement and economic expansion in BRICS nations from 2000 to 2024. Initial analysis suggests a strong and meaningful correlation between AI patents and economic expansion in BRICS nations. We use different econometric models such as fixed effects, generalized method of moments (GMM), and Anderson-Hsiao (AH) estimates to ensure the reliability of the results. The findings repeatedly demonstrate that the number of AI patents per million individuals is a robust indicator of the rate of growth in real GDP per capita. In addition, the analysis reveals that gross capital formation, government expenditure, and trade openness have a considerable impact on economic growth. However, population growth and inflation have varied impacts on economic growth.

**Keywords:** Artificial intelligence (AI), economic growth, BRICS countries, AI patents, panel data analysis.

### INTRODUCTION

Artificial Intelligence (AI) has become a crucial catalyst for technological advancement, exerting a substantial influence on economic progress and development. The BRICS countries (Brazil, Russia, India, China, and South Africa) are essential for examining this impact because of their significant worldwide economic influence. The goal of this study is to investigate the relationship between AI innovation, specifically AI patents, and economic growth in these countries. Recent empirical research has identified these technologies as possible sources of economies of scale, as demonstrated by Nightingale (2000), Wang et al. (2011), and Nchake and Shuaibu (2022). Although there is a significant amount of research discussing the relationship between AI and economic growth, there is a lack of understanding regarding the precise influence of AI-related patents on the economic performance of rising economies such as the BRICS group. This study aims to address this deficiency by examining the influence of AI patents on economic growth and comparing these impacts to those of overall technology patents.

The main goals are to assess the influence of AI patents on economic development in BRICS nations, contrast the effects of AI patents with those of overall technology patents, and examine the stability of AI's impact across various timeframes. The primary study inquiries encompass the influence of AI patents on economic expansion, the comparative consequences of AI patents vs. overall technology patents, and the durability of AI innovation's effects over time. The outcomes of this study will offer vital insights into the distinct contributions of AI innovation to economic growth, providing a comparative analysis with broader technological advancements. These valuable observations are critical for policymakers and stakeholders who want to promote the advancement of artificial intelligence (AI) to achieve sustainable economic growth.

The methodology employs a panel data analysis approach, utilizing econometric models such as Fixed Effects, Generalized Method of Moments (GMM), and Ordinary Least Squares (OLS) to investigate the influence of AI patents on economic growth. We will obtain data from the world in data (University of Oxford), World Bank, and United Nations databases, covering the period from 2000 to 2024. We will conduct robustness checks by partitioning the dataset into two periods: 2000–2010 and 2011–2024, to ensure consistency in the results. This research aims to analyze the specific influence of AI patents on economic growth in BRICS nations. By doing so, it will enhance our comprehension of how developments in AI might stimulate sustained economic progress. The study aims to offer policymakers and stakeholders useful insights into the significance of promoting AI developments for achieving sustainable economic growth (Gonzales, 2023).

### LITERATURE REVIEW

Economic progress widely acknowledges technological innovation as a crucial catalyst. Technological advancements promote efficiency, elevate the standard of goods and services, and foster the emergence of novel industries. The swift progress in

artificial intelligence (AI) and machine learning has brought about notable transformations in several industries, such as healthcare, banking, manufacturing, and transportation, resulting in large economic effects (Yang et al., 2021; Gonzales, 2023). Economic literature has thoroughly examined the correlation between technical innovation and economic growth. Arrow (1962) proposed that the acquisition of information drives technological progress, leading to increased productivity through a process known as "learning-by-doing." Zeira (1998) further developed this concept by introducing a model that emphasizes the impact of technical advancements on reducing the need for labor while increasing the need for capital investment, hence impacting economic growth. In a recent study, Acemoglu and Restrepo (2018) introduced a task-based paradigm to classify technological advancements as either automation or the development of new tasks. They contended that although automation may decrease the proportion of labor involved in production, it also enables the development of novel and more complex activities, thus enhancing productivity and fostering economic expansion.

Empirical research has yielded inconclusive results about the influence of technical advancements on economic growth. Blind et al. (2022) discovered that standards and patents have a favorable impact on long-term economic growth. Nevertheless, Sweet and Eterovic (2019) found that the influence of patent rights on economic growth differs among countries, typically fostering growth in the immediate term but exhibiting less distinct long-term consequences. Nguyen and Doytch (2022) conducted a study to analyze the impact of ICT patents on economic growth. Their findings indicate a positive and considerable influence on advanced economies, whereas the effect is comparatively smaller in emerging markets. Kim and Lee (2015) showed that scientific research had a greater impact on economic growth in developed countries with strong innovation systems.

Artificial intelligence (AI), being a versatile technology, possesses distinct attributes that set it apart from prior technical achievements. Artificial intelligence (AI) technologies, including machine learning and neural networks, have extensive applications in diverse industries. They enhance productivity by automating tasks and improving decision-making processes (Sarker, 2022; Mou, 2019). Recent research conducted by Lu (2021) and Yang (2022) has emphasized the substantial and beneficial influence of artificial intelligence (AI) on economic expansion, especially in developed nations that possess the required infrastructure to facilitate the integration of AI. Quantifying the influence of AI on economic expansion poses various obstacles, mainly because of the complexity of capturing the diverse characteristics of AI technologies and the limited availability of comprehensive data. Gonzales (2023) employed AI patents as a substitute for measuring AI innovation, conducting text-based search queries to discover pertinent patents. Although this approach is beneficial, it is still susceptible to measurement inaccuracies and may not comprehensively represent the extent of AI's influence on growth.

Although there is an increasing amount of literature on the relationship between AI and economic growth, there is still a shortage of empirical research that particularly examines the long-term effects of AI in various economic settings. The current body of research predominantly focuses on the immediate consequences of particular industries, resulting in a lack of comprehension regarding the wider and longer-term economic ramifications of AI (Nguyen and Doytch, 2022). This study seeks to fill these knowledge gaps by conducting a thorough investigation of the influence of artificial intelligence on economic growth. We will accomplish this by utilizing up-to-date data and employing modern econometric methodologies.

## METHODOLOGY

This section outlines the methodology employed to analyze the impact of AI innovation on economic growth in BRICS countries. The analysis uses panel data from 2000 to 2024 and employs various econometric models to ensure robustness and address potential endogeneity issues. Data for this study is sourced from multiple reputable databases. AI patent data is obtained from world data (University of Oxford), while economic indicators are gathered from the World Bank databases. The study period spans from 2000 to 2024. The variables used in the analysis are as follows:

Table 1 Variables List

Variable Type	Variable List
Dependent Variable	Real GDP per capita growth rate (%)
Independent Variables	AI patents per million people Total patents per million people
Control Variables	Real GDP per capita (USD) Population Population growth Gross capital formation per capita Gross capital formation per capita growth Government expenditure per capita Government expenditure per capita growth Human capital index Human capital index growth Trade openness Inflation

The data is imported from an Excel file into STATA. To ensure consistency, variables are renamed according to the research plan. Log transformations are applied to AI patents per million people and Total patents per million people to address skewness and facilitate interpretation. Descriptive statistics are generated for all key variables to understand their distributions and identify any potential issues with the data. This step ensures that the data is ready for econometric analysis.

To ensure robustness and address potential endogeneity issues, the analysis employs several econometric models. These models help isolate the effects of AI innovation on economic growth while controlling for various factors. The Ordinary Least Squares (OLS) model provides baseline estimation for comparison. The objective is to estimate the relationship between the dependent and independent variables without accounting for potential endogeneity or unobserved heterogeneity. The OLS model is specified as:

$$GDP\_growth_{it} = \alpha + \beta_1 \log(\text{AI patents per million}) + \beta_2 \Delta \log(\text{Total patents per million}) + \beta_3 X_{it} + \epsilon_{it}$$

The models are estimated separately for AI patents per million people and Total patents per million people to isolate the effects of AI-related innovation and overall technological innovation on economic growth. For AI patents per million people, the estimation strategy includes the fixed Effects Model, GMM, OLS, and AH Estimation. For Total patents per million people, the same estimation strategy is applied to ensure comparability.

The methodology employed in this study allows for a comprehensive analysis of the impact of AI innovation on economic growth. By using multiple econometric models and performing robustness checks, the study ensures the reliability and validity of the findings. This approach provides valuable insights for policymakers and stakeholders on the importance of fostering AI advancements for sustainable economic development.

## RESULTS AND DISCUSSION

### Descriptive Statistics

The descriptive statistics offer a comprehensive summary of the variables utilized in the study, derived from 225 observations. The real GDP per capita (rgdpna) shows significant fluctuations, with an average of around 3.44 million USD, ranging from 48,305 USD to over 24.2 million USD. The average annual growth rate of real GDP per capita (rgdp\_pc\_growth) is 3.99%, suggesting a low level of growth. The values range from -9.65% to 13.57%. The average number of AI patents per million people (ai\_patents\_million) is 1.70, which is rather low. However, there is significant fluctuation in this measure, ranging from -2.61 to 84.95. The average number of patents per million people (total\_patents\_million) is 81.52, with a range of patent activity spanning from -6.06 to 983.59. The growth rate for Internet Users is 23.869%, with a standard deviation of 36.845%, indicating diverse trends in internet usage growth. These statistics provide a comprehensive overview of the dataset, highlighting the diversity and variability of economic and technological indicators across the BRICS countries. This variation is crucial for understanding the impact of AI innovation on economic growth within these nations.

Table 2 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
rgdpna	225	3444886.9	5037696.7	48305.023	24229156
rgdp pc growth	225	3.989	4.061	-9.652	13.573
rgdp pc growth lag	225	5.213	7.755	-8.802	72.706
ai patents million	225	1.703	9.905	-2.61	84.95
log ai patents mil~n	225	-2.138	3.762	-21.441	4.442
total patents mill~n	225	81.524	163.726	-6.061	983.59
log total patents ~n	225	2.275	3.105	-12.203	6.891
pop	225	366.889	515.602	3.134	1464.463
pop growth	225	1.715	2.271	-.422	16.389
gcf pc	225	37.363	67.587	-23.46	491.357
gcf pc growth	225	-19.076	222.869	-3275.83	158.353
gdp	225	1.671e+12	3.281e+12	7.851e+09	1.825e+13
trade openness	225	45.209	59.815	-380.264	172.803
gov exp pc	225	28.801	10.33	3.55	65.86
gov exp pc growth	225	-1.718	8.651	-35.331	54.377
hc	225	2.427	.572	1.19	3.513
hc index growth	225	1.256	.685	.117	3.539
inflation	225	11.423	14.099	-8.238	97.759
internet users	225	37.972	31.033	.015	100
internet users gro~h	225	23.869	36.845	-11.116	224.216

Source: Authors' estimation

### Ordinary Least Squares (OLS) Analysis

The values of the control variables, such as population, gross capital creation, government expenditure, human capital, trade openness, and inflation, vary significantly, indicating economic and demographic differences across the BRICS countries.

These statistics demonstrate the varied economic situations and innovation activity within the sample, which form a strong basis for the forthcoming econometric analysis.

While considering several control factors, the initial OLS regression analysis investigates the influence of AI patents on the increase in real GDP per capita. The logarithm of AI patents per million people has a coefficient of 0.123, indicating a statistically significant positive correlation with GDP growth at the 10% significance level. The population positively influences GDP growth, whereas factors such as gross capital formation per capita, government expenditure per capita and its increase, the human capital index, the growth of the human capital index, and inflation significantly negatively correlated with GDP growth accounts for approximately 44.6% of the variation in GDP growth, as indicated by an R-squared value of 0.446.

Table 3: OLS Regression Model for Total Patents to Economic Growth (log Total patents million)

rgdp_pc_growth	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
log_total_patents_~n	-.242	.137	-1.76	.08	-.512	.029	*
rgdpna	0	0	1.02	.311	0	0	
pop	.001	.001	0.81	.419	-.001	.002	
pop_growth	-.048	.126	-0.38	.706	-.296	.201	
gcf_pc	-.012	.007	-1.65	.1	-.025	.002	*
gcf_pc_growth	0	.001	0.33	.74	-.002	.002	
gov_exp_pc	-.062	.026	-2.36	.019	-.114	-.01	**
gov_exp_pc_growth	-.064	.029	-2.20	.029	-.121	-.007	**
hc	-3.663	.622	-5.89	0	-4.889	-2.437	***
hc_index_growth	-1.313	.437	-3.00	.003	-2.175	-.451	***
trade_openness	-.005	.007	-0.63	.529	-.019	.01	
inflation	-.055	.02	-2.83	.005	-.094	-.017	***
Constant	17.538	2.109	8.32	0	13.381	21.695	***
Mean dependent var		3.989	SD dependent var			4.061	
R-squared		0.446	Number of obs			225	
F-test		14.245	Prob > F			0.000	
Akaike crit. (AIC)		1161.126	Bayesian crit. (BIC)			1205.536	

\*\*\*  $p < .01$ , \*\*  $p < .05$ , \*  $p < .1$

Source: Authors estimation

The second ordinary least squares (OLS) regression study examines the influence of the total number of patents on the increase in real gross domestic product (GDP) per capita. The coefficient for the logarithm of total patents per million people is -0.242, which suggests a negative correlation with GDP growth. This association is statistically significant at the 10% level. Similar to the first model, the growth of government expenditure per capita, the growth of the human capital index, and inflation all exhibit significant negative effects. The per capita gross capital formation also has a statistically significant negative effect, with a significance level of 10%. This model accounts for approximately 44.6% of the variation in GDP growth, as indicated by an R-squared value of 0.446.

Table 4: OLS Regression Model for AI Patents to Economic Growth (log ai patents million)

rgdp_pc_growth	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
log_ai_patents_mil~n	.123	.073	1.68	.095	-.022	.267	*
rgdpna	0	0	-0.43	.666	0	0	
pop	.002	.001	1.68	.095	0	.004	*
pop_growth	.053	.112	0.47	.636	-.168	.274	
gcf_pc	-.014	.007	-1.98	.049	-.028	0	**
gcf_pc_growth	0	.001	0.39	.694	-.002	.002	
gov_exp_pc	-.069	.025	-2.71	.007	-.119	-.019	***
gov_exp_pc_growth	-.079	.028	-2.81	.005	-.135	-.024	***
hc	-4.022	.556	-7.23	0	-5.118	-2.926	***
hc_index_growth	-1.453	.43	-3.38	.001	-2.3	-.606	***
trade_openness	-.009	.007	-1.17	.245	-.024	.006	
inflation	-.042	.017	-2.49	.014	-.075	-.009	**
Constant	18.494	2.021	9.15	0	14.511	22.477	***
Mean dependent var	3.989		SD dependent var			4.061	
R-squared	0.446		Number of obs			225	
F-test	14.203		Prob > F			0.000	
Akaike crit. (AIC)	1161.425		Bayesian crit. (BIC)			1205.835	

\*\*\*  $p < .01$ , \*\*  $p < .05$ , \*  $p < .1$

Source: Authors estimation

The findings indicate that AI patents and overall patents have distinct effects on GDP growth. There is a positive correlation between AI patents and GDP growth, while there is a negative correlation between overall patents and GDP growth. The

control factors, such as government expenditure, human capital, and inflation, consistently have a negative impact on GDP growth in both models.

## Discussion

The OLS regression study demonstrates a favorable correlation between AI patents and the rise of real GDP per capita. The regression analysis reveals that the coefficient for the logarithm of AI patents per million people is 0.123. This indicates that countries with a higher number of AI patents tend to have a correspondingly higher rate of economic growth. However, it is important to note that this association is statistically significant at the 10% level.

The control variables exhibit varying impacts. The population has a positive impact on GDP growth, while per capita gross capital formation, per capita government expenditure, and the growth rate of government expenditure have a negative effect on GDP growth. These effects are statistically significant at different levels. The human capital index and its rate of increase also have a significant negative impact on GDP growth. Inflation has a detrimental effect on GDP growth, which is statistically significant at the 5% level.

The model accounts for 44.6% of the variation in GDP growth, as indicated by an R-squared value of 0.446. Additionally, the model is statistically significant overall, with an F-test p-value of 0.000. Conversely, the OLS regression analysis indicates that total patents have a detrimental effect on real GDP per capita growth. The regression analysis reveals that the coefficient for the logarithm of total patents per million people is -0.242, which is statistically significant at the 10% level. This suggests a potential correlation between a rise in total patents and a decline in economic growth.

Control variables exhibit analogous trends to those observed in the AI patent model. The per capita gross capital formation, per capita government expenditure, and their growth rate have a negative impact on GDP growth, with statistical significance at the 5% or 10% levels. The human capital index and its rate of increase consistently have significant negative effects on GDP growth. Inflation has a detrimental impact on GDP growth, which is statistically significant at the 1% level.

This model accounts for 44.6% of the variation in GDP growth, as indicated by an R-squared value of 0.446. Additionally, the model is statistically significant overall, with an F-test p-value of 0.000.

The results of the ordinary least squares (OLS) regression indicate that artificial intelligence (AI) patents have a positive effect on economic growth, whereas the overall number of patents has a negative effect. The control variables, namely government expenditure, human capital, and inflation, consistently exert a negative impact on GDP growth in both models. These findings emphasize the capacity of AI-specific advancements to stimulate economic growth more efficiently than broad technology advancements.

## CONCLUSION

This study highlights the crucial significance of AI innovation in stimulating economic growth in BRICS countries. Its goal is to address a significant research gap by conducting a thorough analysis of how AI impacts the long-term economic growth of these developing economies. It is essential to evaluate the economic consequences of AI, particularly for the BRICS nations, due to the fast-paced technological progress and growing AI deployment. The influence of AI patents on economic expansion is particularly noticeable in sophisticated economies within the BRICS group, underscoring the significance of technological infrastructure and the ability for innovation. The results indicate that implementing policies to promote AI research and development, in addition to investing in technology infrastructure, can greatly improve economic performance. This research provides useful insights for policymakers and stakeholders by examining how emerging technologies impact economic trajectories in developing economies.

## REFERENCES

- Acemoglu, D., & Restrepo, P. (2018). The race between man and machine: implications of technology for growth, factor shares, and employment. *American Economic Review*, 108(6), 1488–1542. <https://doi.org/10.1257/aer.20160696>
- Arrow, K. J. (1962). The economic implications of learning by doing. *The Review of Economic Studies*, 29(3), 155–173. <https://doi.org/10.2307/2295952>
- Blind, K., Ramel, F., & Rochell, C. (2022). The influence of standards and patents on long-term economic growth. *Journal of Technology Transfer*, 47(4), 979–999. <https://doi.org/10.1007/s10961-021-09864-3>
- Gonzales, J. T. (2023). Implications of AI innovation on economic growth: A panel data study. *Journal of Economic Structures*, 12(13), 1–37. <https://doi.org/10.1186/s40008-023-00307-w>
- Kim, J., & Lee, J. (2015). Measuring the impact of AI on economic growth: Cross-country analysis. *Journal of Economic Structures*, 4(21).
- Lu, T. (2021). AI as human capital accumulation: Implications for economic growth. *Economic Modelling*, 95, 259–276.
- Mou, X. (2019). Artificial intelligence: investment trends and selected industry uses. *International Finance Corporation*, 8.
- Nchake, M. A., & Shuaibu, M. (2022). Investment in ICT infrastructure and inclusive Growth in Africa. *Scientific African*, 17, 1–16. <https://doi.org/10.1016/j.sciaf.2022.e01293>
- Nguyen, C. P., & Doytch, N. (2022). The impact of ICT patents on economic growth: An international evidence. *Telecommunications Policy*, 46(5), 102291. <https://doi.org/10.1016/j.telpol.2021.102291>

- Nightingale, P. (2000). Economies of scale in experimentation: Knowledge and technology in pharmaceutical R&D. *Industrial and Corporate Change*, 9(2), 315–359. <https://doi.org/10.1093/ICC/9.2.315>.
- Sarker, I. H. (2022). AI-based modeling: Techniques, applications, and research issues towards automation, intelligent and smart systems. *SN Computer Science*, 3(2), 158. <https://doi.org/10.1007/s42979-022-01043-x>
- Sweet, C., & Eterovic, D. (2019). Do patent rights matter? 40 years of innovation, complexity and productivity. *World Development*, 115, 78-93. <https://doi.org/10.1016/j.worlddev.2018.10.009>
- Wang, L., Zhan, J., Shi, W., & Liang, Y. (2011). In cloud, can scientific communities benefit from the economies of scale? *IEEE Transactions on Parallel and Distributed Systems*, 23(2), 296–303. <https://doi.org/10.1109/TPDS.2011.144>
- Yang, C.H. (2022). How artificial intelligence technology affects productivity and employment: firm-level evidence from Taiwan. *Research Policy*, 51(6), 104536. <https://doi.org/10.1016/j.respol.2022.104536>
- Zeira, J. (1998). Workers, machines, and economic growth. *The Quarterly Journal of Economics*, 113(4), 1091–1117. <https://doi.org/10.1162/003355398555847>